



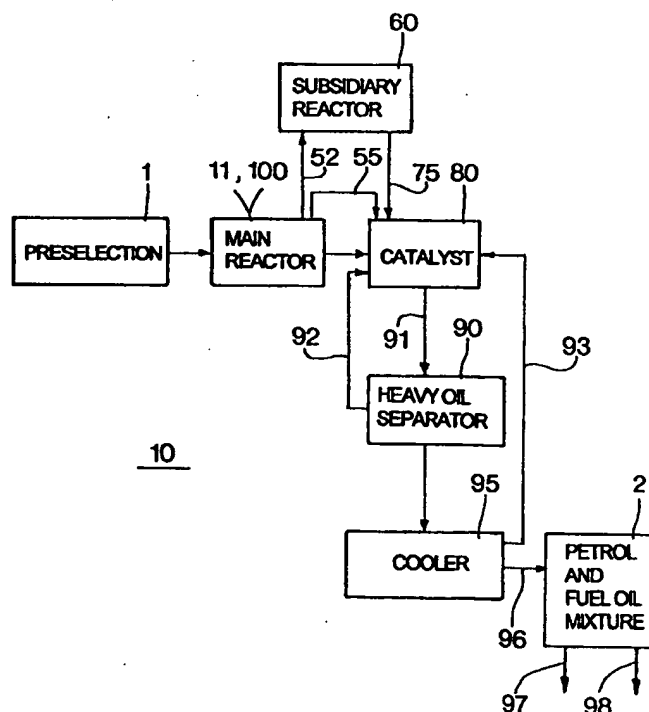
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/IT99/00113 (22) International Filing Date: 3 May 1999 (03.05.99) (30) Priority Data: MI99A000855      23 April 1999 (23.04.99)      IT (71)(72) Applicant and Inventor: TIANFU, Jiang [CN/IT]; Via Bassini 39, I-20100 Milano (IT). (72) Inventors; and (75) Inventors/Applicants (for US only): JUNHONG, Chen [CN/IT]; Via Bassini 39, I-20100 Milano (IT). YANPING, Chen [CN/IT]; Via Bassini 39, I-20100 Milano (IT). CHAUGCHUN, Su [CN/IT]; Via Bassini 39, I-20100 Milano (IT). (74) Agent: DIGIOVANNI, Italo; Brevetti Dott. Ing. Digiovanni Schmiedt SRL, Via Aldrovandi 7, I-20129 Milano (IT).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  Published With international search report.	

(54) Title: PROCESS AND PLANT FOR CONVERTING WASTE PLASTIC MATERIAL INTO COMBUSTIBLE HYDROCARBONS

## (57) Abstract

Process and plant (10) for conversion of plastic material waste (44) into combustible hydrocarbons comprising thermal separation, at about 450 °C and ambient pressure, of said plastic material waste (44) and its transformation into liquid material and then into combustible gaseous hydrocarbons, expulsion of residual material consisting of heterogeneous impurities and separation in a catalyst (80), with AL\*\*\* salts, metal oxides, SiO<sub>3</sub><sup>-</sup>, of said gaseous hydrocarbons into a lesser quantity of gaseous hydrocarbons of small molecules such as CH<sub>4</sub> and C<sub>4</sub>H<sub>10</sub> and the like and in a greater quantity of liquid hydrocarbons consisting of a mixture of petrol and fuel oil.



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10    **Process and plant for converting waste plastic material into  
combustible hydrocarbons**

The invention concerns conversion of urban and industrial waste plastic material into combustible hydrocarbons.

It is well known that urban and industrial waste plastic material,  
15    such as bags and containers for food products as well as objects of plastic material in general, cannot be regenerated; this creates considerable problems of environmental pollution as well as economic loss.

The above process solves these problems applying a technology  
20    that will be described below.

Subject of the invention is a process for converting waste plastic material into combustible hydrocarbons, comprising:

- separation by heat of said plastic waste into combustible gaseous hydrocarbons,
- 25    - catalytic separation of said gaseous hydrocarbons into a lesser quantity of gaseous hydrocarbons of small molecules like  $\text{CH}_4$ ,  $\text{C}_4$ ,  $\text{H}_{10}$  and similar and into a greater quantity of liquid hydrocarbons consisting of a mixture of gasoline or petrol, and fuel oil.

Thermal separation is obtained by continuous feed of the plastic  
30    material, following magnetic preselection by blasts of air or equivalent means, into a main reactor, here called an oven, then

applying heat to liquify it and transformation of most of said liquid material into combustible gaseous hydrocarbons.

The residual material is cyclically expelled from the bottom of the reactor by a specially designed discharger.

- 5 The plastic material is put into the reactor by a feeder comprising a piston, thrust by a series of screws, that in turn, pushes a mass of plastic material through a narrow funnel, and a cooling means.

A suitable space is allowed between the end of the piston stroke and the start of the funnel, in which space the mass of plastic  
10 material creates a kind of mobile plug which prevents the gaseous hydrocarbons from flowing out.

The reactor is heated by placing it in an oven with a chamber in which hot air is produced by a burner; said hot air enters from below and is discharged at the top.

- 15 A part of the liquid plastic, obtained by thermal separation, and the expelled residual material are cyclically transferred to a second reactor, here called a subsidiary reactor substantially similar to the main one, by a discharger situated lower down so as to maintain the liquid in the main reactor at a constantly optimal level.

- 20 The subsidiary reactor comprises a system of heating consisting of electromagnetic coils that surround its walls.

In the reactors is a beater with an axial shaft at the lower end of which are blades, the shaft being connected uppermost to an electric motor.

- 25 Temperature inside the reactors is maintained at about 450°C.

Catalytic separation is obtained by putting gaseous hydrocarbons into a catalyst with salts of  $Al^{+++}$ , metal oxides,  $SiO_3^-$  and other similar products.

- The salts are placed in a group formed of several hundred tubes  
30 below which is a group of ceramic balls.

This catalyst is surrounded by an oven that maintains its temperature at about 450°C.

On leaving the catalyst the gaseous hydrocarbons are transferred to a separator of heavy hydrocarbons from which these latter return  
5 passing through a tube upstream of the catalyst while the light gaseous hydrocarbons are sent to a cooler.

The greater part is condensed into liquid hydrocarbons formed of a mixture of petrol and fuel oil while the lesser quantity of gaseous hydrocarbons of small molecules, such as  $\text{CH}_4$  and  $\text{C}_4\text{H}_{10}$  and the  
10 like, go to the oven surrounding the catalyst and are used to heat it. Thermal separation can alternatively be obtained by continuous feed of the plastic material into what is here called a tube reactor and heated to liquid form till most of said liquid is transformed into combustible gaseous hydrocarbons.

15 In said reactor are two oblong substantially cylindrical chambers aligned one with the other.

Inside said chambers and in line with their axis is a tubular shaft driven by an electric motor and surrounded by a pair of Archimedean screws, one in the upper chamber and one in the lower one  
20 from whose base the residual material is continually extracted.

A heating system is provided consisting of three electromagnetic coils arranged in sequence and independent, two round the upper chamber, here called the fusion chamber, and one round the lower chamber, here called the separation chamber.

25 Starting from the top of the reactor a temperature of about 200°C can thus be set at the first coil, a temperature of about 450-500°C at the third coil and an intermediate temperature at the second coil.

The plastic material put in through a feeder at the top of the upper chamber is thus transformed into a liquid state and then, passing  
30 into the lower chamber, becomes gaseous, after which it is discharged in gaseous form, through devices at said lower chamber

and through said tubular shaft, from a mouth at the top.

From there, through a tube, the gaseous hydrocarbons are taken to the catalyst where the process already described is substantially repeated.

- 5 Residual material is continually eliminated by a discharger at the base of the lower chamber

Pressure inside the reactors is environmental pressure.

The reactors can be heated by gas, fuel oil, or electromagnetic coils as the case may be.

- 10 The described plant may function vertically, horizontally or at a certain angle.

The invention offers evident advantages.

The process here described requires no washing or crushing of the plastic waste and, since the conditions necessary for obtaining the  
15 reaction of thermal separation are simply atmospheric pressure, an environment with a low level of oxygen and a normal industrial temperature around 450°C, small quantities of paper, textile fabric and food can be eliminated together with other residual material such as dust and the like.

- 20 Combined use of thermal separation and catalytic separation at normal pressure makes possible optimum recycling at a low cost

Processing of urban waste becomes a complete industrial cycle in which the non-regenerable plastic is transformed into an economic form of non-polluting energy that can also supply heat to other  
25 processes for utilising waste such as oven-drying of organic fertilizers.

The technology here described thus provides an essential link to form a complete and perfect chain of industries dealing with waste.

- Characteristics and purposes of the disclosure will be made still  
30 clearer by the following examples of its execution illustrated by diagrammatically drawn figures.

Figure 1. Diagram of the operational cycle of the invented process.

Figure 2 Diagram of the plant for carrying out the process.

Figure 3. Diagram of an alternative plant.

The plant 10 comprises a reactor 11, here called an oven reactor, in which "thermal separation" is carried out, with a chamber 12 in which is the beater 15 with its blades 16 supported by an axial shaft 18 rotated by an electric motor 19.

This reactor is inserted in the oven 30 comprising the heating chamber 31 which receives air heated by the flame burner 40 through a nozzle 33 at the level 32.

The hot air emerges through the mouth 35 at the top of the chamber 31.

After passing through a magnetic preselector 1, or being blown by air, the waste plastic is introduced in a continuous manner into the reactor 11 through the feeder 45 comprising an Archimedean screw 46, a piston 47, a funnel 48 and a water cooler 49.

During the feed movement, the piston 47 is pressed as far as the position seen in Figure 2.

Between the beginning of the funnel 48 and the piston 47, a dense lump of plastic material 44 will thus be maintained forming a plug that prevents any outward flow of gaseous hydrocarbons.

The plastic material is kept at a certain level of temperature by the cooler 49.

An hydraulic piston can be used in place of the screw.

Temperature of the hot air circulating in the oven is 650-700°C ensuring a temperature of about 450°C in the chamber 12 and this, at environmental pressure, liquifies most of the plastic material.

About 70% of the liquid plastic is transformed into gaseous hydrocarbons of a molecular weight much lower than that of the plastic material

About 30% of the liquid plastic non transformed into hydrocarbons,

together with remaining residual matter consisting of heterogeneous impurities such as small pieces of paper, textiles, food, dust, burnt objects, earth and anything else, is cyclically sent through the discharger 50, with its downward rotating Archimedean screw 51, to the lower end of the reactor, and from there through the duct 52 to the subsidiary reactor 60 where thermal separation is completed, in order to keep the liquid in the main reactor 11 at optimal level 38.

On completing the discharging operation, the screw 52 rotates upwards and the bottom of the reactor 11 is closed.

In the subsidiary reactor 60 is a chamber 61 to house the beater 70 with shaft 71 and blades 72, driven by the electric motor 73.

The chamber 61 is heated by a group 62 of electromagnetic coils, at 45 kW for example, to keep its internal temperature constant at about 450°C

Residual material is expelled through the discharger 67 with its Archimedean screw 68.

The gaseous hydrocarbons generated by the main reactor 11 and by the subsidiary reactor 60 are sent through respective ducts 55 and 75 to the catalyst 80.

This catalyst is formed of a molecule filter 81 having 200-400 tubes containing inside them the catalysing product consisting of  $AL^{+++}$  salts, metal oxides,  $SiO_3^-$  and the like.

A group 83 of ceramic balls lie below the tubes.

The catalyst separates the gaseous hydrocarbons into about 10% of small-molecule gaseous hydrocarbons, such as  $CH_4$  and  $C_4H_{10}$ , and into about 90% of gaseous hydrocarbons consisting of a mixture of petrol and fuel oil.

On leaving the catalyst 80 through the duct 85, the gaseous hydrocarbons are sent to the heavy oil separator 90.

The light hydrocarbons in a gaseous state pass through the tube 91 into the cooler 95 while a small quantity of heavy hydrocarbons



returns through tubes 92 and 75 to the catalyst 80.

The lesser quantity of gaseous hydrocarbons of small molecules, like  $\text{CH}_4$  and  $\text{C}_4\text{H}_{10}$ , passes through tube 93 to the oven 94 surrounding the catalyst 80 to make use of its thermal energy, while  
5 the greater quantity of light gaseous hydrocarbons liquifies forming a mixture of petrol and fuel oil utilizable through the duct 96.

These are high quality hydrocarbons and can be used to produce pure petrol and fuel oil by sending them to the refinery as indicated by the arrow 97, or else they can be used immediately as indicated  
10 by the arrow 98, to supply heat for conversion into electric energy or for other purposes.

The main thermal separation reactor 11 can supply the catalyst 80 at a rate of between 3 and 10 tonnes per day.

Every 6-8 hours a part of the liquid material is sent to the subsidiary  
15 reactor 60 and from there the gaseous hydrocarbons obtained are similarly transferred for about 8 hours to the catalyst 80.

Figure 3 illustrates an alternative to the oven-type reactor 11 described, namely a tube-type reactor 100 for thermal separation, comprising a chamber 101 and another chamber 102 below it  
20 connected by a duct 103.

Inside there is the tubular shaft 11 of an axial beater 110 rotated by the electric motor 112.

Inside the chamber 101, said shaft 111 supports the Archimedean screw 115, and a similar screw 116 inside the lower chamber 102.

25 Around the chamber 101 is an electromagnetic coil 120 followed downward by the electromagnetic coil 121, while the electromagnetic coil 123 is placed round the chamber 102 underneath.

In this way three areas of differing temperatures are created, varying from about  $200^\circ$  to  $500^\circ\text{C}$  starting from the first coil.

30 The selected plastic material is continuously fed into the reactor 100 through the feeder 130 and hopper 131.

The beater 110 slowly pushes the plastic material upwards in the reactor to the position of coil 120.

On reaching the coil 121, all the material liquifies and at the area 123, the effect of the temperature between 450° and 500°C initiates  
5 the process of thermal separation generating hydrocarbons in a gaseous state.

Through devices 136 and through the tubular shaft 111, these hydrocarbons emerge from the mouth 140 and on to the catalyst 80 through the duct 141.

10 Residual material from thermal separation is slowly pushed to the bottom of the chamber 102 from where it is continuously expelled through the discharger 145 driven by the electric motor 146.

Daily output is between 7.5 and 30 tonnes.

As the description clearly explains, gas, combustible oils, electro-  
15 magnetic coils and other means can be used to heat the separating reactors 11 and the residual materials 60.

Temperatures are comprised between 150° and 900°C.

The plant described may operate vertically, horizontally or at a certain angle, as the case may require.

Claims

1. Process for conversion of plastic material waste (44) into combustible hydrocarbons,  
characterized in that it comprises thermal separation of said plastic  
5 material waste (44) into gaseous combustible hydrocarbons, expulsion of residual material consisting of heterogeneous impurities, and catalytic separation of said gaseous hydrocarbons into a lesser quantity of gaseous hydrocarbons of a small molecule such as  $\text{CH}_4$  and  $\text{C}_4 \text{H}_{10}$  and the like and into a greater quantity of liquid hydrocarbons consisting of a mixture of petrol and fuel oil.  
10
2. Process for conversion of plastic material waste (44) into combustible hydrocarbons as in claim 1,  
characterized in that thermal separation is obtained by continuously feeding the plastic material (44), following magnetic preselection  
15 with blasts of air or equivalent means, into a main reactor (11) here called an oven reactor, provided with a heating system (30) and subjecting said plastic material (44) to heat until it is transformed into liquid material and transformation of the greater part of said liquid material into combustible gaseous hydrocarbons, the residual  
20 material being cyclically expelled from the base of the reactor (11) by a specially made discharger (50).
3. Process for conversion of plastic material waste (44) into combustible hydrocarbons, as in claim 2,  
characterized in that the plastic material (44) is fed into the reactor  
25 (11) by a feeder (45) comprising a piston (47), thrust by a series of screws (46), that in turn pushes a mass of plastic material through a narrow funnel (48) and a cooling system (49), there being between the full stroke of the piston (47) and the start of the funnel (48) an adequate space where the mass of plastic material (44)  
30 forms a kind of mobile plug the purpose of which is to prevent outflow of gaseous hydrocarbons.

4. Process for conversion of plastic material waste (44) into combustible hydrocarbons, as in claim 2,  
characterized in that the reactor (11) is heated by insertion inside an oven (30) having a chamber (31) heated by hot air produced by  
5 a flamer burner (40), said air entering low down in the chamber and being discharged at its top (35).
5. Process for conversion of plastic material waste (44) into combustible hydrocarbons, as in claim 2,  
characterized in that a part of the liquid plastic material obtained by  
10 thermal separation and the expelled residual material are cyclically transferred to a second reactor, here called a subsidiary reactor (60) substantially similar to the main reactor (11), by a discharger (67) situated lower down, so as constantly to maintain the liquid in the main reactor (11) at an optimal level (38).
- 15 6. Process for conversion of plastic material waste (44) into combustible hydrocarbons, as in claim 5,  
characterized in that the subsidiary reactor comprises a heating system provided by electromagnetic coils (62) that surround its walls.
- 20 7. Process for conversion of plastic material waste (44) into combustible hydrocarbons, as in claims 2 and 5,  
characterized in that the reactors (11, 60) present a beater (15, 70) with an axial shaft (18, 71) that carries blades (16, 72) at its lower end and that is connected at the top to an electric motor (19, 73).
- 25 8. Process for conversion of plastic material waste (44) into combustible hydrocarbons, as in claims 2 and 5,  
characterized in that temperature inside the reactors (11, 60) is kept at about 450°C:
9. Process for conversion of plastic material waste (44) into com-  
30 bustible hydrocarbons, as in claim 1,

characterized in that catalytic separation is obtained by feeding the gaseous hydrocarbons into a catalyst (80) containing salts of  $Al^{+++}$ , metal oxides,  $SiO_3^-$  and other similar products.

10. Process for conversion of plastic material waste (44) into combustible hydrocarbons, as in claim 9,

characterized in that the salts are placed in a group (83) of ceramic balls, said catalyst (80) being maintained at a temperature of about  $450^{\circ}C$  by an oven (94) that surrounds it.

11. Process for conversion of plastic material waste (44) into combustible hydrocarbons, as in claim 9,

characterized in that, on leaving the catalyst (80), the gaseous hydrocarbons are transferred to a separator (90) of heavy hydrocarbons from which said heavy hydrocarbons are returned, through suitable tubes (92, 75, 55) upstream of the catalyst (80) while the light gaseous hydrocarbons are transferred to a cooler (95) where the greater part is condensed into liquid hydrocarbons consisting of a mixture of petrol and fuel oil, the lesser quantity of gaseous hydrocarbons of a small molecule, such as  $CH_4$  and  $C_4H_{10}$  and the like, being transferred to the oven (94) surrounding the catalyst (80) to be used for heating it.

12. Process for conversion of plastic material waste (44) into combustible hydrocarbons as in claims 1, 9, 11,

characterized in that thermal separation is obtained by continuously feeding the plastic material (44), after magnetic preselection with blasts of air or equivalent means, into a reactor (100), here called a tube reactor, with a heating system and subjecting said plastic material to heat until it liquifies and until most of this liquid material is transformed into combustible gaseous hydrocarbons, said reactor

(100) comprising two oblong substantially cylindrical and aligned chambers (101, 102), there being placed inside said chambers (101, 102) in line with their axis, a tubular shaft (111) driven by an electric motor (112) and surrounded by a pair of Archimedean screws (115, 116), one inside the upper chamber (101) through the top of which the plastic material is put in, and the other inside the lower chamber (102) from whose base (145) the residual material is continually extracted, there being a heating system consisting of three electromagnetic coils (120-122) arranged in sequence and independent, two (120, 121) round the upper chamber (101), here called the fusion chamber, and one (122) round the second lower chamber (102) here called the separation chamber, it being thus possible, starting from the top of the reactor (100) to program a temperature, at the first coil (120), of substantially 200°C, a temperature of substantially 450-500°C at the third coil (123) and an intermediate temperature for the second coil (121), so that the plastic material put in by a special feeding device (130) through the top of the first chamber (101) is transformed in said chamber into a liquid state and, passing into the lower chamber (102) is there transformed into gaseous hydrocarbons which, through special devices (136) placed at said lower chamber and through said tubular shaft (111), are discharged at an uppermost mouth (140) and from there are sent through a tube (141) to the catalyst (80) where the phenomena already described in claims 9 to 11 are substantially repeated, while the residual materials are continuously eliminated by a discharger (145) at the base of the lower chamber (102).

13. Process for conversion of plastic material waste (44) into combustible hydrocarbons as in claims 2, 5 and 12,

30 characterized in that pressure inside the reactors (11,60, 100) is

ambient pressure.

14. Process for conversion of plastic material waste (44) in combustible hydrocarbons, as in claims 2, 5 and 12,

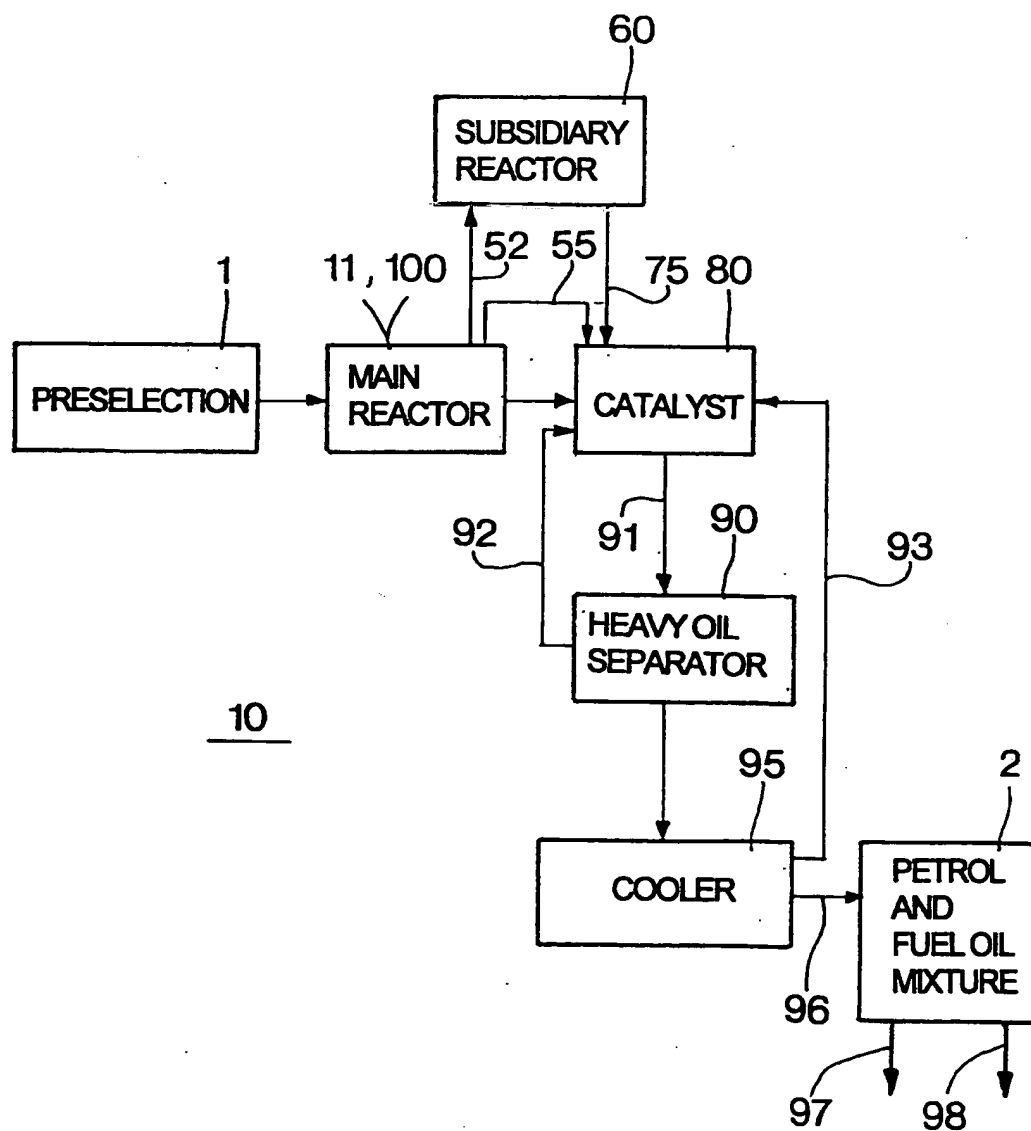
characterized in that the reactors (11, 60, 100) may be heated, as  
5 the case requires, by gas, combustible oil, electromagnetic coils.

15. Plant (10, 100) for executing the process described in claims 1 to 14.

16. Plant (10, 100) as in claim 15,

characterized in that operation may be vertical, horizontal or at a  
10 certain angle as required.

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Fig. 1



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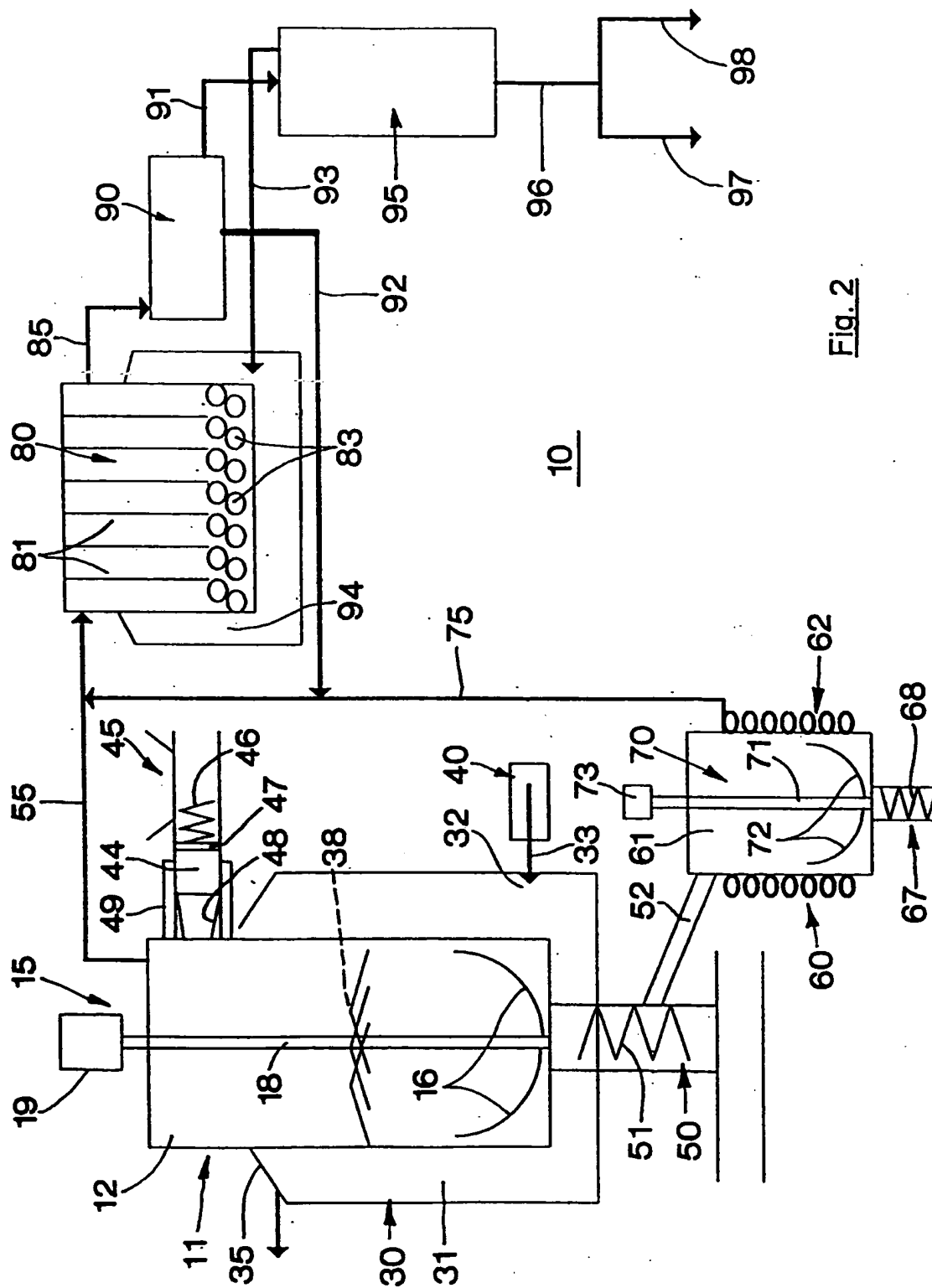


Fig. 2

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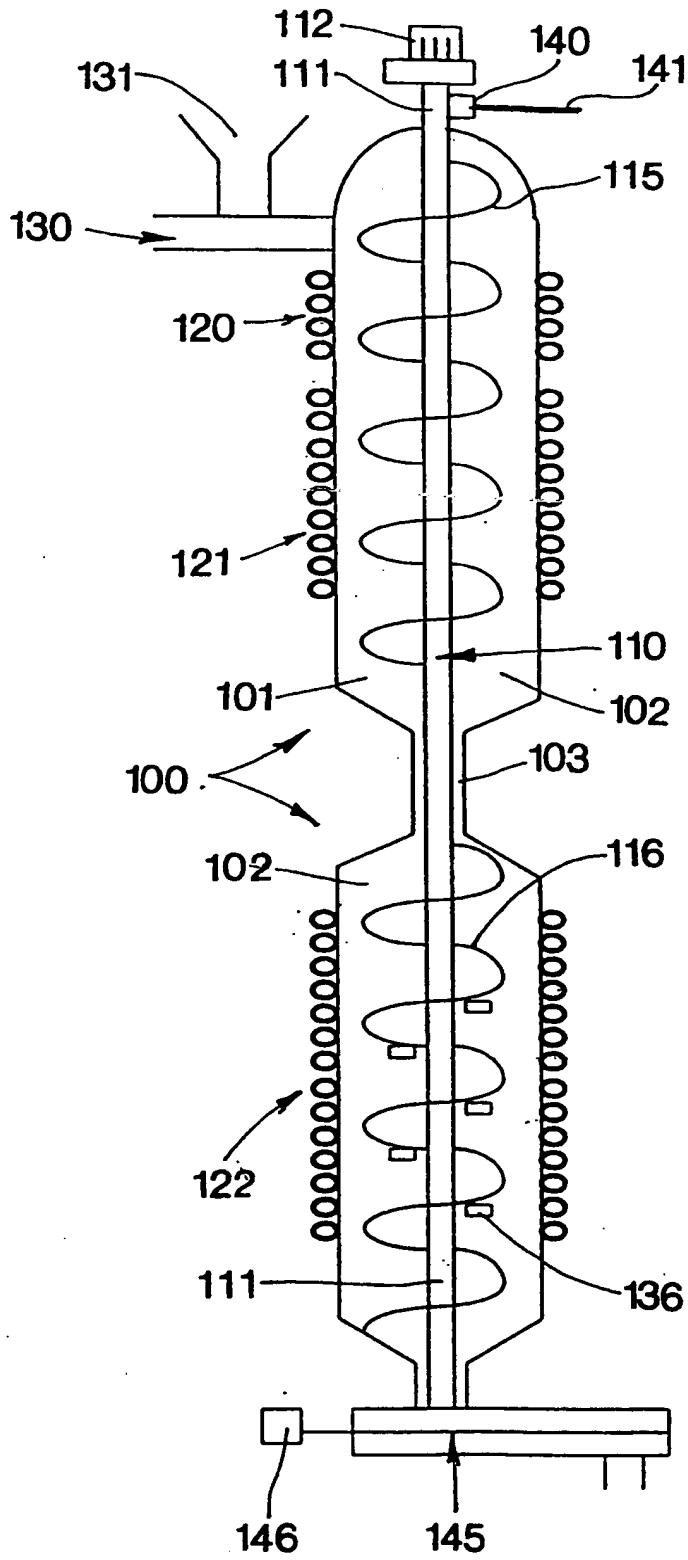


Fig. 3

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/IT 99/00113

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C10G1/00 C10G1/10 C10B19/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C10G C10B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A  A	<p>EP 0 607 862 A (MAZDA MOTOR) 27 July 1994 (1994-07-27)</p> <p>claims 1,3 figures 1,2</p> <p>EP 0 863 197 A (XING LI) 9 September 1998 (1998-09-09)</p>	<p>1</p> <p>2-5,8,9, 15,16</p>

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International Application No

PCT/IT 99/00113

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